The European approach to certifying initial leak tightness

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The European Draft Directive

- According to the Draft Directive relating to emissions from air conditioning systems in motor vehicles « a harmonized leakage detection test for measuring the leakage rate of fluorinated greenhouse gases with a GWP > 150 » has to be implemented.

- In the framework of the type test approval system, a vehicle cannot be placed on the market if the requirements on leakage rates (40 g/yr for single evaporator and 60 g/yr for dual evaporator systems) are not fullfilled.

European type test approval

- The European Commission and ACEA have defined the principles of a type test procedure for an accurate measurement of the leakage from MAC systems.
- The accuracy and validy of the measurement procedure, which will be verified under real life conditions.
- The validation of the method of test has to be completed within the last quarter of 2005.

ACEA specifications

- ACEA has launched a study in order to demonstrate such a method.
- The main specifications address
  - Pre-conditioning of the MAC components
  - Demonstration of the accuracy of the test method
  - Measurements of leak flow rates of complete MAC systems
  - Measurements of leak flow rates of all and every components of the MAC systems
  - Verification of the method on a fleet test.

Pre-conditioning

- All components have to be pre-conditioned under saturating pressure of HFC-134a at 50°C and for a duration period between 48 hrs and 240 hrs. The longest period corresponding to AC lines.
- The compressor when tested alone has to be pre-conditioned during 72 hrs at 50°C, and has to be run at least 1 min.

Demonstration of the accuracy of the test method

- The calibration method has to be performed at 50°C.
- The measurement shall demonstrate that it is independent of the background emissions including VOC.
- The accuracy of the concentration measurement has to reach ± 0.05 g/yr after conversion.
- The calibration has to be performed with 3 different concentrations.

Measurements of leak flow rates of components

- Different methods of test are available but only R-134a, as a tracer gas, allows to test the components under realistic conditions for R-134a systems.
- The concentration of R-134a can be measured by
  - Gas chromatography
  - Mass spectrometry
  - Catharometry
  - Infra-red spectrophotometry.

Measurements of leak flow rates of components

- Mass spectrometers dedicated to R-134a have been developed in the last five years. It can be used as a sniffer (which implies a dilution of the R-134a) or in a closed evacuated hood.

Measurements of leak flow rates of components

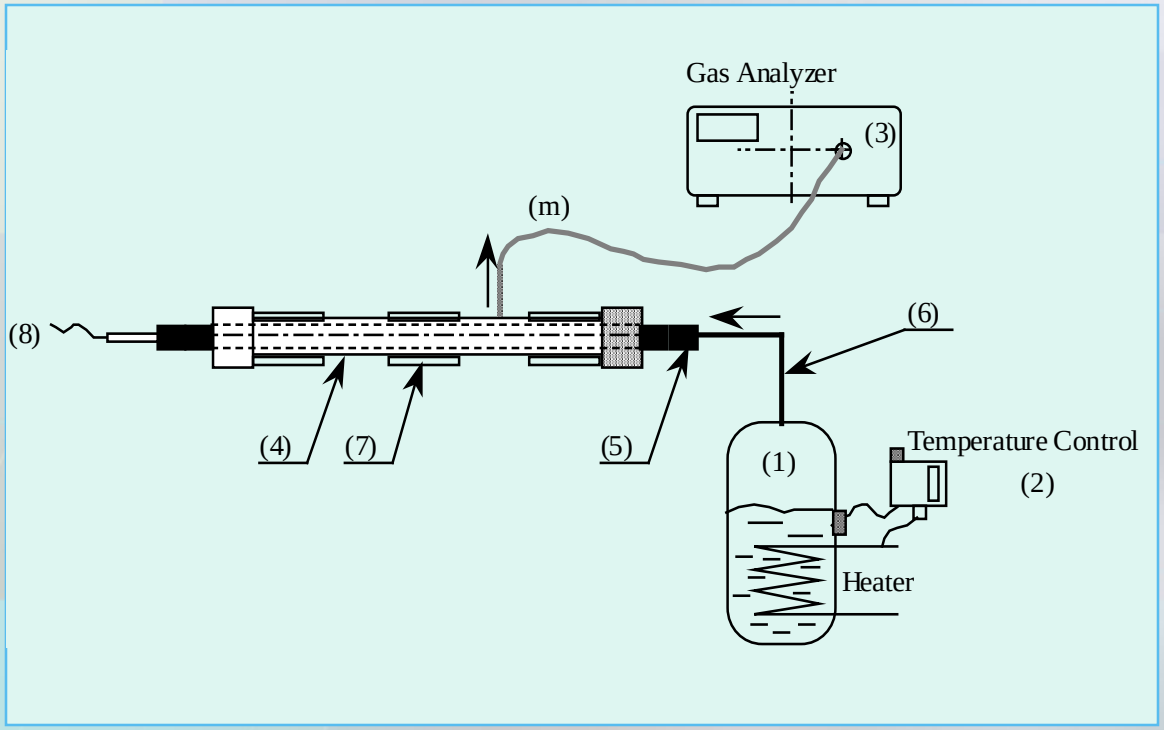
- Gas chromatography shows the highest accuracy for the measurement of the concentration of a defined sample. The main issue of the method is related to sampling in order to make sure that the sample represents adequately the concentration of R-134a in the control volume.

Measurements of leak flow rates of components

- Infra-red spectrophotometry
  - A number of progresses have been made in the last years for the concentration measurements of participating gases. This method has been chosen by the Center for Energy and Processes due to a number of advantages :
    - **Selectivity**
    - **Sensitivity**
    - **Measurement of concentration of 1 ppm ± 1 %**
    - **Continuous measurement of concentration**
    - **Easiness of the method.**

Measurements of leak flow rates of components

- Accumulation method and IR spectrophotometry

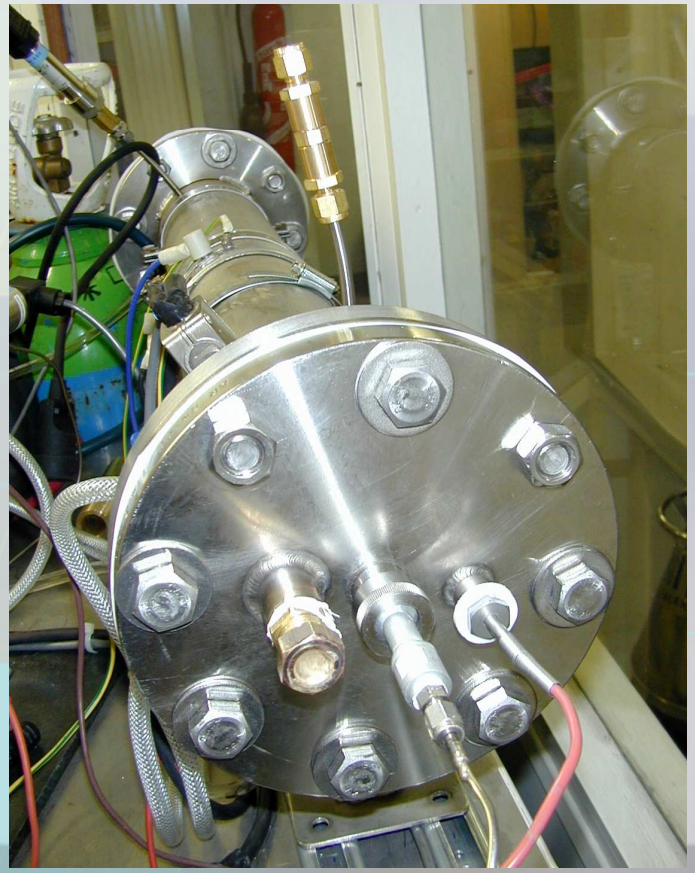


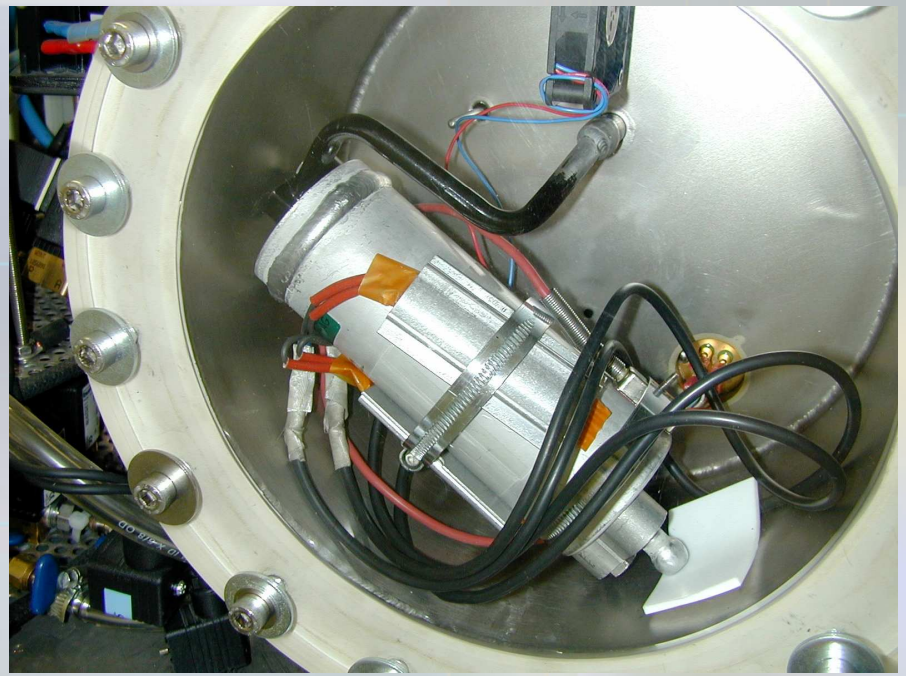
Test bench design for the measurement of components

- Dedicated cells for
  - Hoses
  - Heat exchangers
  - Compressors
  - Lines
  - Fittings, connectors, valves
- Each dedicated cell is designed in order to limit the accumulation volume and consequently to accelerate the concentration measurement. The lower the volume, the faster the concentration raise, and the shorter the measurement time.

Test bench design for the measurement of components

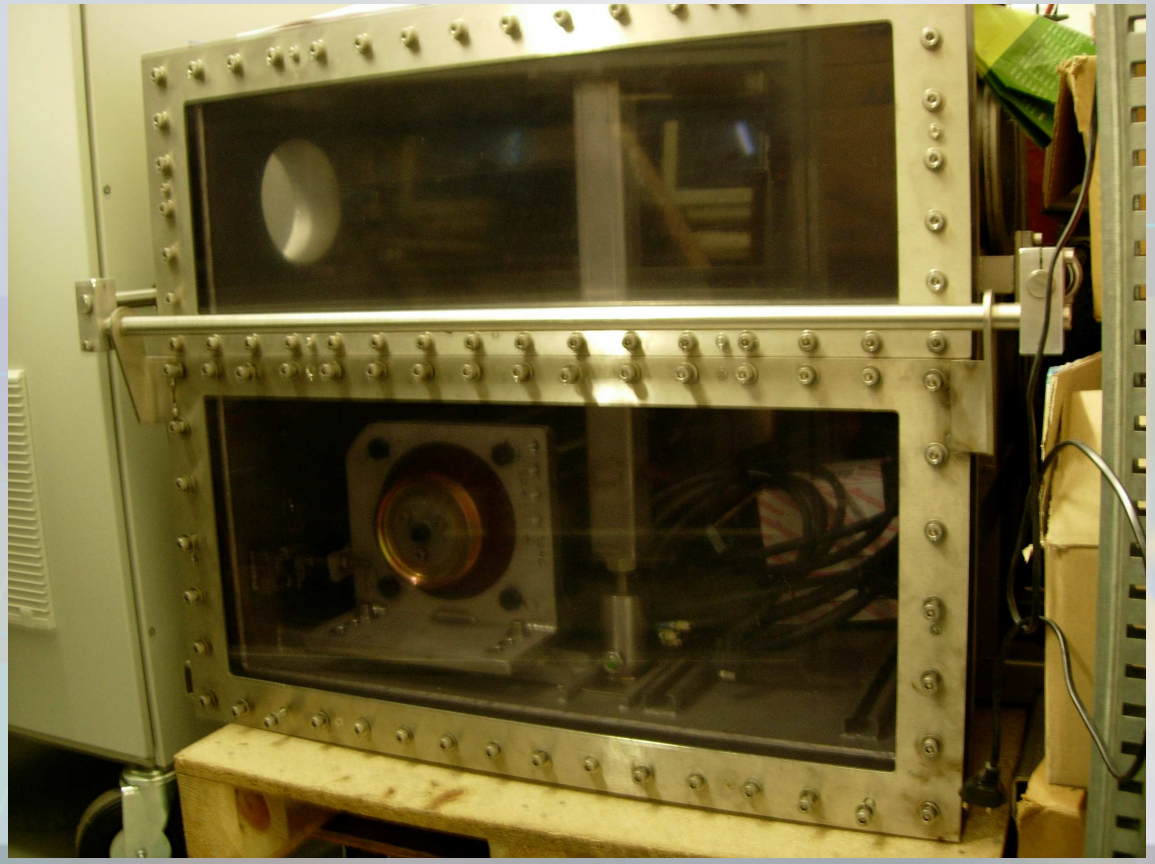
- Accumulation cells for hoses and components





Test bench design for the measurement of components

- Accumulation cell for compressors



Emission law for emission previsions

- **Annual leak flow rate of 20 g/yr of R-134a equals**

Mass flow rate $\dot{m} = 6.34 \bullet 10^{-7}\ g/s$

- **or** Molar flow rate $\dot{N} = 6.22 \bullet 10^{-9}\ mol/s$

- **Equivalent to**

Gas flux $\dot{G} = 1.5 \bullet 10^{-5}\ Pa.m^3/s$

Emission law for emission previsions

- For under pressure equipment, the flow regime is viscous.
- The gas flux for a constant pressure system is written as follows:

$$\dot{G} = p\left(\frac{\partial V}{\partial t}\right)_p$$

- And for a viscous regime

$$\dot{G} = \frac{\pi d^4}{128\, e\, \mu} \frac{\left(p_{upstream}^2 - p_{downstream}^2\right)}{2}$$

Emission law for emission previsions

- In order to forecast the emissions of a complete system, based on the emissions of components, it is necessary to elaborate a behavior law.

- For under pressure systems, leak flow rates follow a general law

$$\dot{G} = C \frac{(p^2_{upstream} - p^2_{downstream})}{2}$$

Emission law for emission previsions

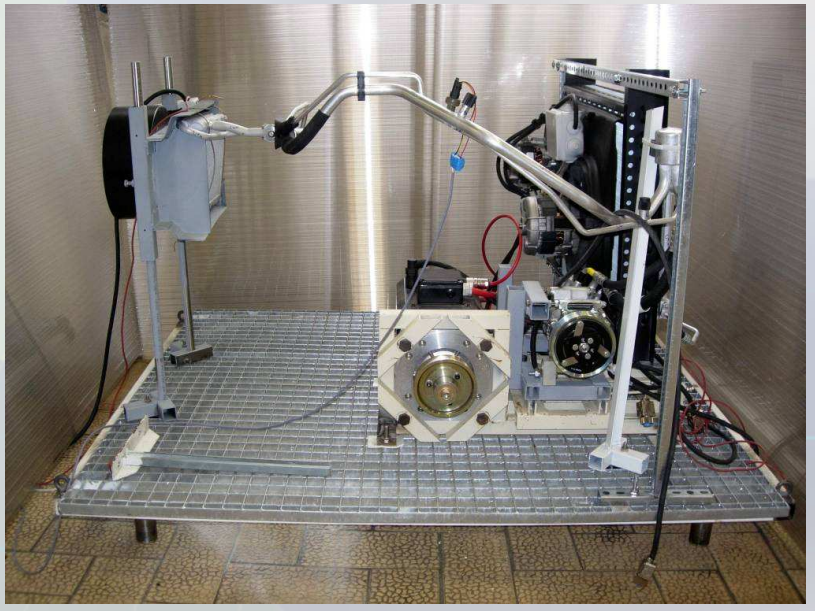
- For such a law, 4 measurement points are necessary:
  - 3 for the elaboration of the law, and
  - 1 for verification.
- When having dependence of leak flow rates from the internal pressure, which depends on the saturation curve of R-134a, it is possible to forecast the emissions for any climatic conditions using meteorological records on an hour-by-hour basis, for the standstill conditions.
- The standstill period for a passenger car represents between 93 and 95 % of the annual use.

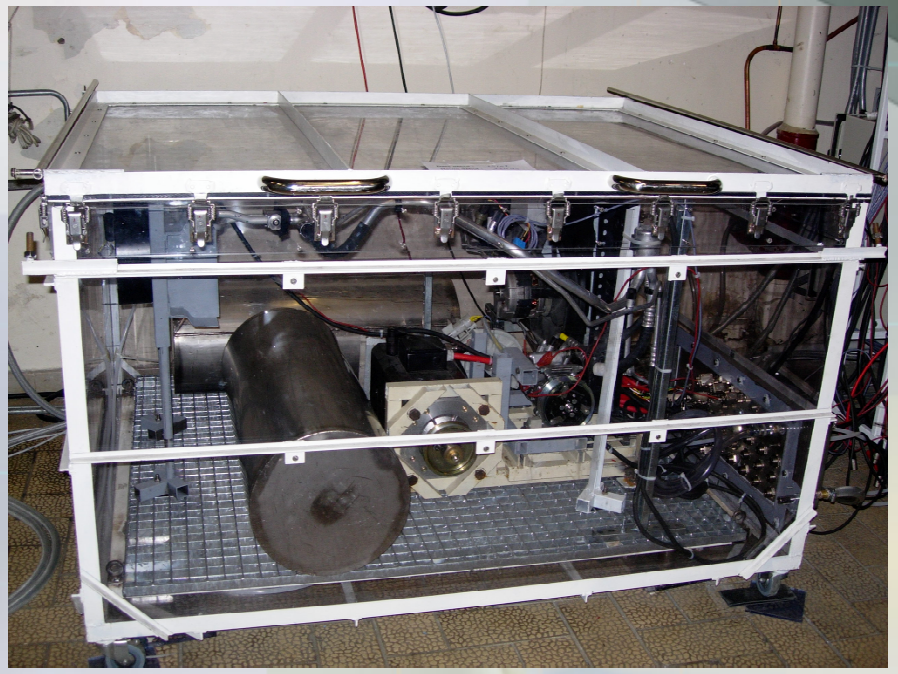
Consistency of the method

- In order to verify that the sum of the leak flow rates of all components correspond to the leak flow rate of the system, this system leak flow rate has to be directly measured.

Measurements of leak flow rates of MAC systems

- The mini-shed concept





- In order to measure the MAC system leak flow rate, a tight mini-shed has been designed with supports permitting to install « any » types of MAC systems.

Measurements of leak flow rates of MAC systems

- The same methodology is used as for the components. The mini-shed is equipped with a heating and ventilation system that permits to control different temperatures inside the mini-shed.

- The MAC system is charges with its original refrigerant charge and 4 different pressures are controlled in order to establish the emission law of the system.

Consistency of the method of test

- Based on the tests of all components of a defined AC system, and of the measurement of the leak flow rate of the system itself, the comparison of the two results:
  - Σ component leak flow rates = leak flow rate of the system
  - This equation will be verified or not for 4 different pressures and for the global result of the annual prevision.

Lessons learnt from the comparison

- Based on the comparison of the accuracies of :
  - the component-based method

  or
  - the system-based method,

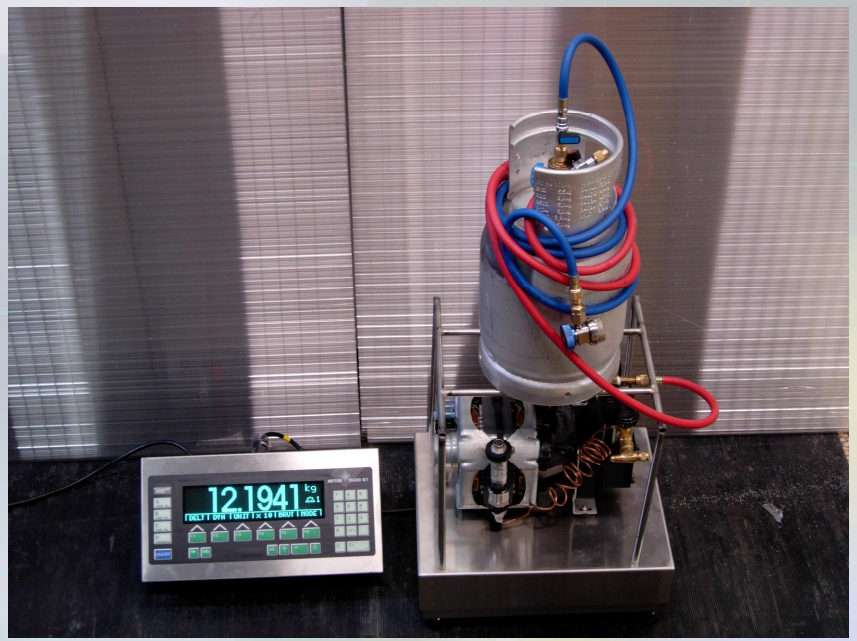
  it will be concluded if
  - one or
  - the other, or
  - both

  is(are) the reference method(s).

Verification on a fleet of air conditioned cars

Precise charge of R-134a
and precise recovery one year later.

- In order to verify that the emissions as predicted by the component-by-component method and the global method are reliable, tests on a fleet of vehicles have to be performed.
- The key issue is to transform the recovery method in a measurement method with an accuracy of 1 to 2 g per year.



Verification on a fleet of air conditioned cars

- In order to reach such an accuracy, the method has to be demonstrated.
- The first step is to evacuate the MAC system at an absolute pressure of about 15 kPa.
- This level of pressure has to be reached identically when the refrigerant is recovered one year later.
- A careful refrigerant charge is performed using scales with a minimum accuracy of 0.1 g.
- A number of precautions have to be taken in order to avoid any refrigerant losses during the charging process.

Verification on a fleet of air conditioned cars

- The AC system is run during at least 30 minutes.
- Then the recovery process is carefully performed.
- The recovery method needs to minimize the oil content of the recovered refrigerant.
- To limit the oil transfer inside the refrigerant, the AC system needs to be heated, at least at 40°C, the recovery mass flow rate needs to be in vapor phase, and with a low velocity.
- The recovery has to be performed down to the same initial pressure (15 kPa abs.).

Verification on a fleet of air conditioned cars

- The recovery process is stopped at this level, the AC system is heated.
- A new refrigerant recovery is performed as the pressure has raised due to refrigerant outgasing from the oil.
- Depending on the complexity of the AC system, the recovery process could be performed several times.
- The criterion for ending the process is that the recovered quantity is lower than 1 g at the last recovery.

Verification on a fleet of air conditioned cars

- The recovered mass (refrigerant + possible oil) is distillated by heating the recovery cylinder connected to another larger cylinder.
- The distillation process is low and the recovery cylinder is heated up to 70°C at the end of the distillation process.
- Then the recovery capacity is evacuated down to 10 Pa abs.
- The remaining mass in the cylinder is oil.

Comparison of the measurement in standstill conditions vs the fleet test

- The main difference between the real life conditions, including the summer period, and the standstill test **is the operation time of the MAC system over a year**.
- As mentioned by different publications, the emissions from the compressor shaft seal are higher in running mode than in standstill mode for a same operating pressure.
- Based on the differences between the standstill tests and the real life tests, a correction factor « c » will be possibly elaborated to integrate the higher leak rate during the running time.

Conclusions

The ex-ante method of test will be demonstrated through the following steps.

- Measurements of leak flow rates of all components,
  - development of emission law for all components,
  - calculation of the annual emission depending on climatic conditions,
- Measurements of leak flow rates of systems with the same method of test

Conclusions

- Comparison of the results of
  - Σ of MAC component leak flow rates = emission of the MAC system
  - Choice of a method of test
- Verification of actual emissions on a fleet of vehicles by comparison of initial charge and recovered charge after 1 year.
- Elaboration of a possible correction factor integrating the running time.

Perspectives

- How to have a global common perspective on measurements of leak tightness?
- Synergies with European leakage measurement are welcome.